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· · USDA FOREST SERVICE RESEARCH NOTE

PNW-197

March 1973

ESTIMATING DUNNING'S SITE INDEX FROM PLANT INDICATORS

by

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PSW FOREST AND RANGE
EXPERIM[illegible]
AUG 23 1973
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ABSTRACT

In California, selective cutting often removes most or all trees suitable for measuring site index. For such areas, an alternative method is described whereby site index is related, through multiple regression analysis, to the occurrence of indicator plants and certain physical variables.

Four equations are presented for estimating Dunning's site index: one for each of four geographic areas covering about 70 percent of California's forest land. The equations account for 55 to 64 percent of the total variation in site index. Independent tests indicate that they predict site index with a standard error of estimate averaging about 20 feet at the base age of 300 years.

Keywords: Site index, classification, indicator plants.

OREST SERVICE - U.S. DEPARTMENT OF AGRICULTURE - PORTLAND, OREGON

INTRODUCTION

Dunning's site class[1] is a widely accepted measure of timber productivity throughout the mixed conifer forests of California. It is intended for use in the mixed-age, mixed-species stands that typify much of that State's forests. Although not associated with yield tables, these site classes are widely used to rank lands by their capacity to grow timber.

Estimates of Dunning's site class are derived from a family of six site-curves harmonized to intercept 25-foot intervals at the reference age of 300 years. Although Dunning intended that they be expressed in discrete classes, the use of the continuous variable form--site index--is often more convenient.

Site index is determined by measuring the height and age of typical dominant trees in the stand--a procedure that poses no particular problem as long as the dominant trees are present. However, many California stands have been selectively logged, leaving only the shorter codominant and intermediate trees. In other areas, the trees have been destroyed by fire, leaving a semipermanent brush field in their place. In both cases, the absence of dominant trees makes conventional site class measurements impossible or unreliable. In addition, many areas are stocked with trees too young to permit reliable estimates of site index. In short, substantial areas of forest land lack suitable site trees.

THE STUDY

We recently investigated the possibility of estimating Dunning's site index, using a multiple regression equation based on plant indicators and physical characteristics. This study is a byproduct of a larger study aimed at improving estimates of productivity.[2] In that investigation, we used multiple regression analysis of plant indicators and other likely variables such as slope, aspect, and elevation to develop equations for predicting stocking capacity. Many of these same factors have proved useful in predicting Dunning's site index. Thus, we have been able to use data collected for the productivity study to develop site index prediction equations for four geographic areas covering a large part of California.

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[1] Duncan Dunning. A site classification for the mixed conifer selection forests of the Sierra Nevada. USDA Forest Serv. Calif. Forest & Range Exp. Stn. Res. Note 28, 21 p., 1942.

[2] Colin D. MacLean and Charles L. Bolsinger. Estimating productivity on sites with a low stocking capacity. Pac. Northwest Forest & Range Exp. Stn. USDA Forest Serv. Res. Pap. PNW-152, 18 p., illus., 1973.

DEVELOPING THE EQUATIONS

Our approach was suggested by the work of James Griffin[3] who related Dunning's site class to elevation and a soil drought index developed by him for use in eastern Shasta County, California. Griffin also demonstrated that soil drought index could be replaced by vegetative drought index--a soil moisture rating determined by the species of plants that occur on a site. However, rather than use vegetative drought index, we elected to relate the plant species growing on a site directly to the site class.

Dunning's site index was measured for the productivity study on 81 to 177 well-distributed locations in each of four separate geographic areas (fig. 1) chosen on the basis of climate, geology, and, to some extent, Forest Survey work plans. Area 3 bounds area 4 on the Sierra Divide. Otherwise, the boundaries conform either to county lines or the lower limits of commercial forest. Sampling covered the range of natural conditions but was restricted to relatively undisturbed locations. We visited each location once during the growing season and identified all recognizable plant species. We also recorded latitude and such topographic features as slope, aspect, elevation, soil depth, and physiographic class.

Plots were located in stands with uniform site characteristics. At each location, we measured the height and age of several dominant trees and searched an area of about an acre to insure finding all species of plants. The only plant species not recorded were those growing on microsites with obviously different site characteristics--i.e., rock outcrops and abandoned roadbeds.

For each unit, the species list was reduced to about 60 by screening out plants that were either hard to identify or apparently unrelated to site index. The list was further reduced by grouping plants that often grow together. The remaining plants and plant groupings plus the various topographic variables were entered in a stepwise multiple regression program with each species or species group treated as a dummy variable with a value of 1 if present and 0 if absent. Dunning's site index--the dependent variable--was entered as precisely as it could be read from Dunning's site curves.

From this analysis, we developed four equations--one for predicting Dunning's site index in each of the four geographic areas. The variation accounted for ranged from 55 to 64 percent (table 1), and the standard errors of estimate averaged about 20 feet when measured against the basic study data.

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[3] James R. Griffin. Soil moisture and vegetation patterns in northern California forests. Pac. Southwest Forest & Range Exp. Stn. USDA Forest Serv. Res. Pap. PSW-46, 22 p., 1967.

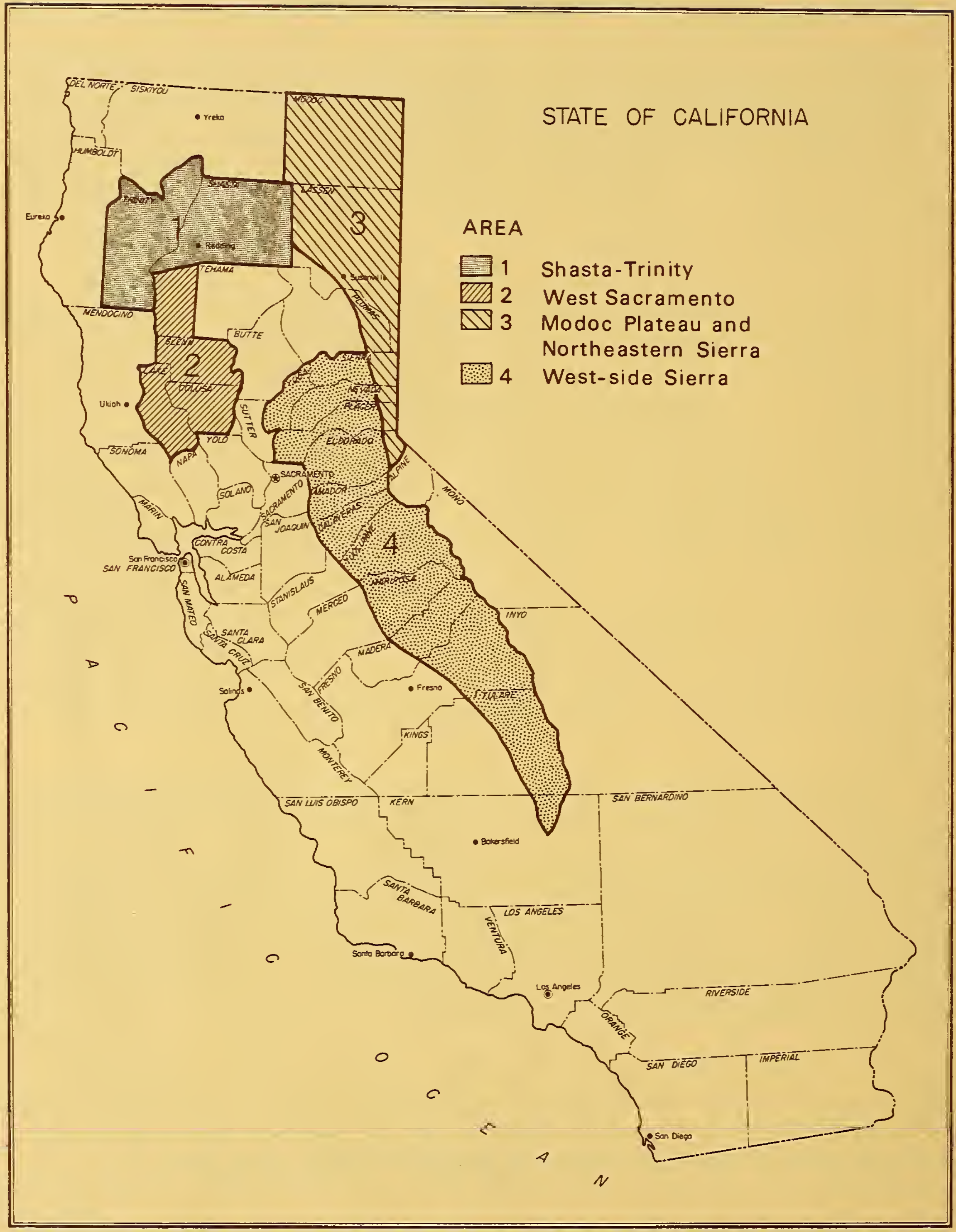

Figure 1.–State of California showing the four geographic areas sampled for this study.

Table 1.--*Reliability of equations for predicting Dunning's site index for four geographic areas in California*

Reliability indicators	Shasta and Trinity	West Sacramento	Modoc Plateau and Northeastern Sierra	West-side Sierra
Number of plots to develop equation	97	81	95	177
R^2	0.64	0.55	0.55	0.60
Standard error of estimate (feet)	19.4	21.8	14.3	18.6
Number of plots in independent test	162	22	89	55
Standard error of estimate for independent test (feet)	20.3	21.4	14.6	19.8
Equation bias in independent test (feet)[1]	+0.2	+5.5	-0.4	-0.2

[1] Average amount by which equation estimates exceeded or fell short of field measured site index.

We also tested each of the equations against field data not used in the regression analysis. The test plots sampled disturbed conditions, particularly partial cuts, much more heavily than the original sample. In other respects, the test plots generally represented the same range of conditions sampled for the regression analysis in all areas except the west Sacramento area. There, the few test plots available to us sampled a narrow range of site indices. Further testing of this equation would be desirable.

We anticipated that the test results might show the equations to be less reliable than the multiple regression analysis would indicate. This proved true, but the drop in precision was small (see table 1). Equation results were neither significantly higher nor lower than field measured site index. The small amount of bias that did occur--5.5 feet in the west Sacramento area--was probably an accident of sampling.

Although many of the test plots had been heavily logged, the equations appeared to work here as well as on undisturbed areas. This finding agrees with Griffin's (see footnote 3) observation that "most of the 'usable' indicator plants can be found in most habitats even after drastic disturbance." Of necessity, the test plots were restricted to sites where suitable site trees were available. We, therefore, lack data on the reliability of the equations under conditions of extreme disturbance--for example, severe burns or clearcuts. Dyrness,[4] however, working in western Oregon, found plant species to be remarkably persistent, even after clearcutting and burning. Small, unburned remnants of the original ground vegetation proved particularly helpful.

We suspect that the equations may work less well in areas where the tree overstory has been replaced by a semipermanent brush cover. Still, we are not aware of any better means to objectively estimate site index on such areas.

THE EQUATIONS

The four equations follow. All independent variables are "dummy variables" with a value of 1 if present and 0 if absent, except for elevation which is recorded to the nearest 100 feet and latitude which is recorded to the nearest degree. Plant groupings are recorded as present if any of the species in the group is found.

Area 1 (Shasta and Trinity Counties)

$$\text{Dunning's site index} = 138 - 28X_1 - 16X_2 - 10X_3 + 18X_4 + 25X_5 + 15X_6 + 8X_7 + 20X_8 - 9X_9 - 20X_{10} - 24X_{11} - 20X_{12} + 18X_{13}$$

Where:

X_1 = *Pinus monticola* (western white pine)[5]

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[4] C. T. Dyrness. Early stages of plant succession following logging and burning in the western Cascades of Oregon. Ecology 54(1): 57-69, illus., 1973.

[5] Scientific names of grasses, herbs, and shrubs follow Philip A. Munz and David D. Keck, A California flora. Univ. Calif. Press, Berkeley, Calif., 1,681 p., illus., 1970. Names of trees follow E. L. Little, Jr., Check list of native and naturalized trees of the United States (including Alaska), U.S. Dep. Agric. Agric. Handb. 41, 472 p., illus., 1953.

X_2 = *Ceanothus cuneatus* (wedgeleaf ceanothus), *Cercocarpus betuloides* (birchleaf mountain-mahogany) or *C. ledifolius* (curlleaf mountain-mahogany)
X_3 = *Rhamnus californica* ssp. *tomentella* (coffeeberry) or *Prunus subcordata* (Sierra plum)
X_4 = *Abies concolor* (white fir)
X_5 = *Castanopsis sempervirens* (bush chinkapin) or *Prunus emarginata* (bitter cherry)
X_6 = *Pteridium aquilinum* (bracken fern)
X_7 = *Quercus kelloggii* (California black oak)
X_8 = *Adenocaulon bicolor* (trail plant), *Disporum* spp. (fairy bells), or *Osmorhiza chilensis* (sweet cicely)
X_9 = *Pterospora andromedea* (pine drops), *Chimaphila umbellata* var. *occidentalis* (prince's pine), or *Smilacina* spp. (false solomon seal)
X_{10} = *Campanula prenanthoides* (California harebell)
X_{11} = *Arctostaphylos patula* (greenleaf manzanita)
X_{12} = *Castilleja applegatei* (paint brush), *Clarkia rhomboidea* (forest clarkia), *Delphinium nuttallianum* (Nuttall larkspur), or *Juniperus occidentalis* (western juniper)
X_{13} = *Wyethia mollis* (woolly mule's ears) or *Balsamorhiza* spp. (balsam root)

Area 2 (Colusa, Glenn, Lake, and western Tehama Counties)

$$\text{Dunning's site index} = 149 + 13X_1 - 15X_2 - 28X_3 - 11X_4 + 24X_5 - 10X_6 + 16X_7 + 23X_8 - 10X_9 - 17X_{10} - 11X_{11}$$

Where:

X_1 = *Rhus diversiloba* (poison oak)
X_2 = *Arctostaphylos canescens* (hoary manzanita)
X_3 = *Arctostaphylos manzanita* (common manzanita) or *A. viscida* (whiteleaf manzanita)
X_4 = *Ceanothus cordulatus* (mountain whitethorn) or *C. integerrimus* (deer brush)
X_5 = *Rosa gymnocarpa* (wood rose)
X_6 = *Phlox speciosa* ssp. *occidentalis* (low shrubby phlox)
X_7 = *Pyrola picta* (white-veined shin-leaf)
X_8 = *Montia perfoliata* (miners' lettuce), *Sanicula bipinnatifida* (purple sanicle), or *Stipa californica* (California stipa)
X_9 = *Carex multicaulis* (many stem sedge)

X_{10} = *Pinus sabiniana* (digger pine), *Quercus garryana* (Oregon white oak), *Q. garryana* var. *breweri* (Brewer oak), or *Q. dumosa* (California scrub oak)

X_{11} = shallow soil (soil depth of 1-1/2 feet or less)

Area 3 (Modoc, Lassen, eastern Plumas, eastern Sierra, eastern Nevada, eastern Placer, eastern Eldorado Counties)

$$\text{Dunning's site index} = 155 - 5X_1 - 6X_2 - 15X_3 + 11X_4 - 6X_5 + 7X_6 - 13X_7 + 16X_8 + 4X_9 - 19X_{10} - 12X_{11} - 0.008X_{12}$$

Where:

X_1 = shallow soil (soil depth of 1-1/2 feet or less)

X_2 = *Montia perfoliata* (miners' lettuce) or *Geum ciliatum* (prairie smoke)

X_3 = *Cercocarpus ledifolius* (curlleaf mountain-mahogany) or *C. betuloides* (birchleaf mountain-mahogany)

X_4 = *Achillea lanulosa* (western yarrow)

X_5 = *Clarkia rhomboidea* (forest clarkia) or *Eriophyllum lanatum* (woolly sunflower)

X_6 = *Osmorhiza chilensis* (sweet cicely), *Smilacina* spp. (false solomon seal), *Chimaphila umbellata* var. *occidentalis* (prince's pine), *Pterospora andromedea* (pine drops), *Pyrola picta* (white-veined shin-leaf), or *P. picta forma aphylla* (leafless pyrola)

X_7 = *Bromus tectorum* (cheat grass) or *Stipa comata* (needle and thread grass)

X_8 = *Abies magnifica* (California red fir)

X_9 = *Ribes* spp. (gooseberry or currant)

X_{10} = *Linanthus ciliatus* or *L. nuttallii* (linanthus)

X_{11} = *Pinus monticola* (western white pine)

X_{12} = $(\text{elevation})^2$

Area 4 (Yuba, western Sierra, western Nevada, western Placer, western Eldorado, Amador, Calaveras, Tuolumne, Mariposa, Madera, Fresno, Tulare, and Kern Counties)

$$\text{Dunning's site index} = 247 - 0.53X_1 - 2.33X_2 - 22X_3 - 14X_4 + 10X_5 - 8X_6 - 15X_7 + 13X_8 - 10X_9 + 17X_{10} + 12X_{11} - 10X_{12} - 21X_{13} + 11X_{14} + 7X_{15} - 10X_{16} + 0.0188X_{2,2}$$

Where:
X_1 = elevation
X_2 = latitude
X_3 = shallow soil (less than 2 feet deep)
X_4 = *Pinus jeffreyi* (Jeffrey pine)
X_5 = *Ceanothus integerrimus* (deer brush), *C. cordulatus* (mountain whitethorn), or *Ribes roezlii* (Sierra gooseberry)
X_6 = *Stipa californica*, *S. occidentalis*, *S. elmeri* (needlegrass), *Sitanion hystrix* (bottlebrush squirreltail), or *Festuca* spp. (annual fescue)
X_7 = *Corylus californica* (California hazel), *Rubus leucodermis* (western raspberry), or *R. parviflorus* (thimbleberry)
X_8 = *Adenocaulon bicolor* (trail plant), *Disporum* spp. (fairy bells), *Goodyera oblongifolia* (rattlesnake plantain), *Viola lobata* (pine violet), *Pyrola picta* (white-veined shin-leaf), or *P. picta forma aphylla* (leafless pyrola)
X_9 = *Eriogonum latifolium* spp. *nudum*, *E. marifolium*, *E. umbellatum* or *E. virgatum* (wild buckwheat), or *Pedicularis semibarbata* (lousewort)
X_{10} = *Clarkia rhomboidea* (forest clarkia)
X_{11} = *Osmorhiza* spp. (sweet cicely) or *Asarum* spp. (wild ginger)
X_{12} = *Wyethia mollis* (woolly mule's ears) or *Balsamorhiza* spp. (balsam root)
X_{13} = area falls in Kern County (an area where the indicators are associated with a somewhat lower site than the rest of the Sierra)
X_{14} = *Pteridium aquilinum* (bracken fern)
X_{15} = *Abies concolor* (white fir)
X_{16} = *Pinus ponderosa* (ponderosa pine)
$X_{2,2}$ = (latitude)^2

USING THE EQUATIONS

The equations are easy to apply. All that is needed is a search of the general area to ascertain which of the plants and other variables are present. The search should be careful enough to find those plants whose occurrence is typically scattered--pine drops, for example. Plants growing on microsites such as springs, rock outcrops, or skid roads should be ignored--all others should be counted even if scarce. Tree species that have been removed through disturbance should also be counted as indicators.

Although learning to identify a dozen or more shrubs, herbs, and grasses may seem a formidable task to some foresters, it really is not. Forest Survey fieldmen--many of them college students from eastern schools--quickly learned to do a satisfactory job of plant identification. Although some of the names may be strange, the plants themselves are familiar to anyone with experience in California forests. Preliminary identification may require the use of one of the many available plant keys or a visit to an herbarium. Others may then be trained quickly by using fresh or pressed specimens.

Substantial areas of northern California were outside the study area. Application of these equations to such areas involves considerable risk of errors and should not be attempted without preliminary testing.

GPO 987-859

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